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Case report

Bone metabolism of residual ridge beneath the denture base of an RPD observed using NaF-PET/CT

Hanako Suenaga DDS, PhD[a,*], Masayoshi Yokoyama DDS, PhD[a], Keiichiro Yamaguchi MD, PhD[b], Keiichi Sasaki DDS, PhD[a]

[a] *Division of Advanced Prosthetic Dentistry, Tohoku University Graduate School of Dentistry, 4-1 Seiryo-machi, Aoba-ku, Sendai, 980-8575, Japan*
[b] *Department of Radiology, Sendai Kousei Hospital, 4-15 Hirose-machi, Aoba-ku, Sendai, 980-0873, Japan*

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Abstract

Patient: A 66-year-old woman, who had a bilateral free-end edentulous mandible and no experience with dentures, was examined for the chief complaint of masticatory dysfunction on left side of dental arch. A unilateral distal extension removable partial denture (RPD) replacing lower-left molars was selected. Tomographic images were obtained using Fluorine-18 NaF positron emission computerized tomography (NaF-PET)/computed tomography (CT) before the RPD use and at 1, 6, and 13 weeks after the RPD use to observe the metabolic changes in residual bone caused by the RPD use. PET standardized uptake values (SUVs) and CT values were calculated for lower-left edentulous site (test side) and lower-right edentulous site (control side). As a result, SUVs on the control side remained static after the RPD use, whereas those on the test side increased at 1 and 6 weeks after the RPD use and then decreased. However, CT images showed no obvious changes in the bone shape and structure beneath RPD, and CT values both on the control and test sides did not change either.
Discussion: This report shows that NaF-PET could detect bone metabolic changes soon after the RPD use, which cannot be detected by clinical X-rays. The SUV changes may be a mechanobiological reaction to the pressure due to the RPD use, and wearing of the RPD may increase the bone turnover beneath denture.
Conclusion: This report demonstrates that wearing of an RPD increases bone turnover beneath denture immediately after the RPD use without clinically detectable changes in bone structure or volume.

Keywords: NaF-PET; Bone metabolism; Residual ridge; RPD

1. Introduction

Excessive pressure by wearing mal-adapting dentures is well known to cause bone resorption beneath the denture base [1]. The structure and volume of the bone are maintained by tireless bone metabolism so that bone deformation is the consequence of the bone metabolic changes. Therefore, we need to figure out the metabolic changes, as a mechanobiological reaction, in the residual bone beneath the denture base and to control it by considering the design of the denture [2,3]. X-rays have been commonly utilized in clinical practice to evaluate the changes in the bone beneath the denture. However, X-ray images merely detect relatively large changes in bone shape and structure, whereas nuclear scanning such as bone scintigraphy, single-photon emission computerized tomography, and positron emission computerized tomography (PET) can detect functional changes in the bone, which occur prior to structural changes. In particular, Fluorine-18 NaF PET (NaF-PET) has received much attention in detecting bone disease such as bone metastases because of its high image quality [4–7]. This case report describes how denture use influences the bone metabolism at the residual ridge beneath the denture base in clinical practice, as determined using NaF-PET/X-ray computed tomography (CT).

2. Outline of the case

2.1. Patient and treatment

The patient was a 66-year-old woman without abnormal bone metabolism such as osteoporosis. Her chief complaint was

* Corresponding author. Tel.: +81 22 717 8369; fax: +81 22 717 8371.
E-mail address: suenaga-thk@umin.ac.jp (H. Suenaga).

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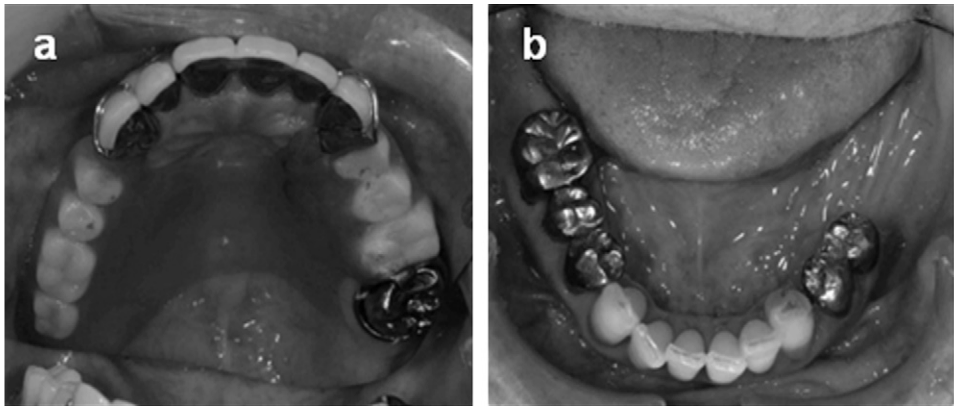

Fig. 1. Intraoral views of the subjects: (a) maxilla; (b) mandible.

masticatory dysfunction on the left side of the dental arch. The mandibular left molars and right second molar had been missing for more than 8 years when she came to the prosthodontic clinic of Tohoku University Hospital, and she had no experience with mandibular dentures (Fig. 1). The patient chose a unilateral distal extension removable partial denture (RPD) replacing the lower-left molars because she had no problem with the right side. A platinum metal base RPD was fabricated and inserted (Fig. 2). The adaptation of the denture base to the residual ridge was checked using white silicon (Fit checker, GC Co., Tokyo, Japan). Occlusal surfaces of the artificial teeth were adjusted to distribute the symmetrical occlusal contacts within the dental arch. Fig. 3 shows the occlusal contact pattern after the adjustment recorded with silicon impression material (Flexicon Injection type, GC Co, Tokyo, Japan). A day after first use of the RPD, a postinsertion adjustment was made. An interview and questionnaire revealed that the masticatory function was improved after the RPD use and that there was no trouble such as pain at the residual ridge beneath the denture base.

Fig. 2. Unilateral distal extension RPD.

Fig. 3. Occlusal contact pattern at intercuspation.

2.2. NaF-PET/CT examination

To examine the metabolic changes in the residual bone beneath the RPD, we performed NaF-PET/CT scans before the RPD use and at 1, 6, and 13 weeks after the first use of the RPD with a PET/CT imaging scanner (Discovery ST Elite, GE Healthcare Japan Co., Tokyo, Japan). Research protocols for this study were approved by the research ethics committee at both the Tohoku University Graduate School of Dentistry and Sendai Kousei Hospital. A signed consent form was obtained after full explanation of the procedures. The emission scans in the three-dimensional acquisition mode with spatial resolutions of 2.0, 2.0, and 3.27 mm in the radial, tangential, and axial directions (Table 1) were started 75 min after intravenous injection of 37 MBq NaF. Because the scan time of the jaw bone was extended from the regular 3 min to 20, a clear PET image was obtained even with a low NaF dosage (1/5 the regular dosage).

The PET images were fused with CT images (Fig. 4) using medical image viewer software (EV Insite R, PSP Co., Tokyo, Japan) to identify the anatomical location. Subsequently, the

Table 1
Scanning condition.

	Field-of view	Matrix	Slice thickness
PET	256 mm	128 × 128	3.27 mm
CT	256 mm	256 × 256	3.75 mm

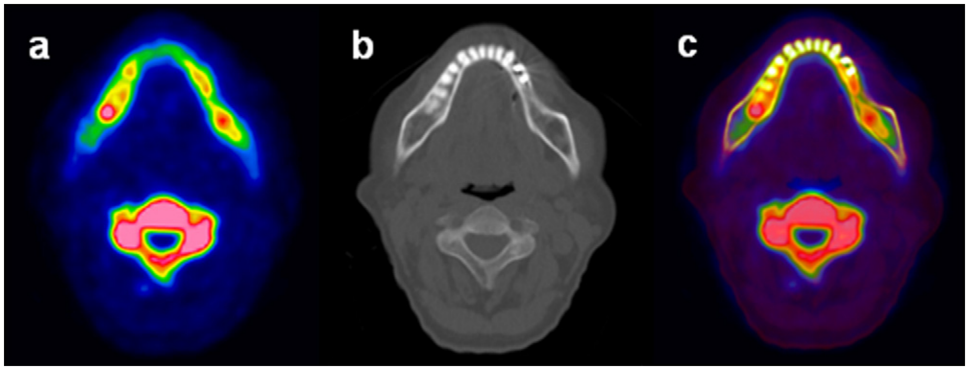

Fig. 4. Transverse images: (a) PET image; (b) CT image; (c) fusion image.

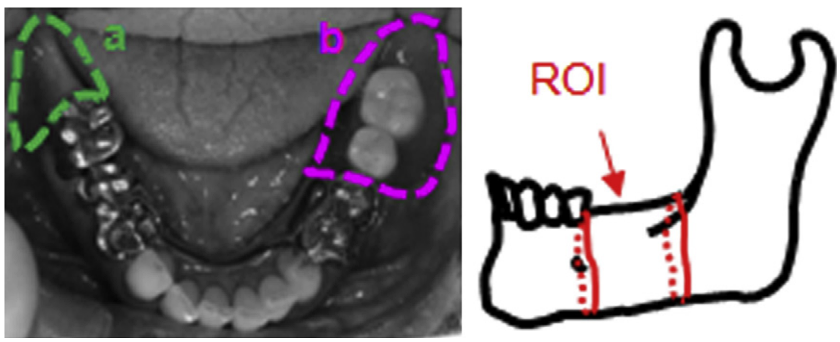

Fig. 5. Definition of ROI. (a) Control side: mandible at the right edentulous site indicated by a green dashed line, which mesial border was the distal end of the right first molar and the distal border was the distal end of retromolar pad. (b) Test side: mandible at the left edentulous site beneath the RPD indicated by a pink dashed line, which included the mandibular bone from the distal end of the left second premolar to the distal border of retromolar pad. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of the article.)

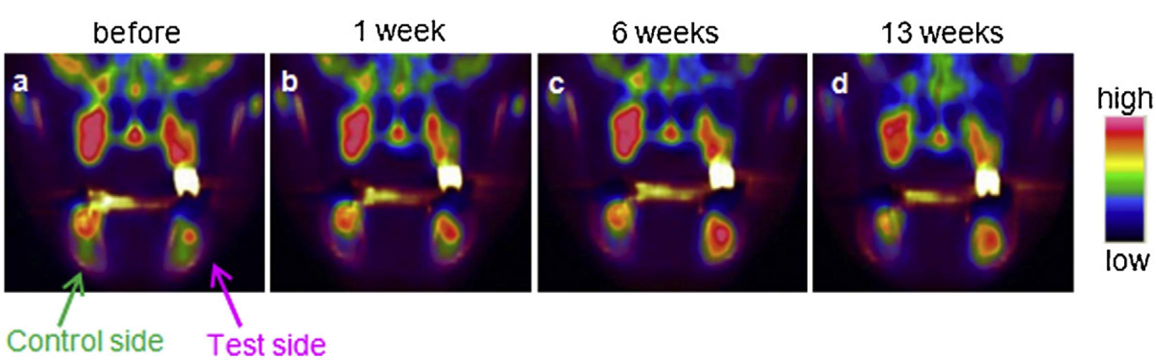

Fig. 6. Coronal multiplanar reconstruction images of accumulation of NaF before RPD use (a) and at 1 week (b), 6 weeks (c), and 13 weeks (d) after RPD use. Accumulation of NaF on the control side remained static after the use of the RPD, whereas that on the test side increased at 1 and 6 weeks after the RPD use and then decreased.

region of interest (ROI) of the test side was placed on her mandible at the left edentulous site beneath the RPD, which included the mandibular bone from the distal end of the left second premolar to the distal border of retromolar pad. The ROI of the control side was set at the right edentulous site, which mesial border was the distal end of the right first molar and the distal border was the distal end of retromolar pad (Fig. 5). CT value and standardized uptake value (SUV) were calculated for each ROI. The SUV was calculated with the following equation to standardize the patient's weight and injected dose: SUV = radioactive concentration (MBq/cc) $\times$ patient weight (g)/injected dose (MBq). The SUV expresses the ratio of the amount of NaF in a certain ROI compared with a situation where the NaF is distributed equally over the entire body. The changes of SUV with respect to time and the difference of SUV between the test side and control side were analyzed.

2.3. Bone metabolic changes after the RPD use

The SUVs on the control side remained static after the RPD use, whereas those on the test side increased at 1 and 6 weeks after the RPD use and then decreased (Figs. 6 and 7a). However,

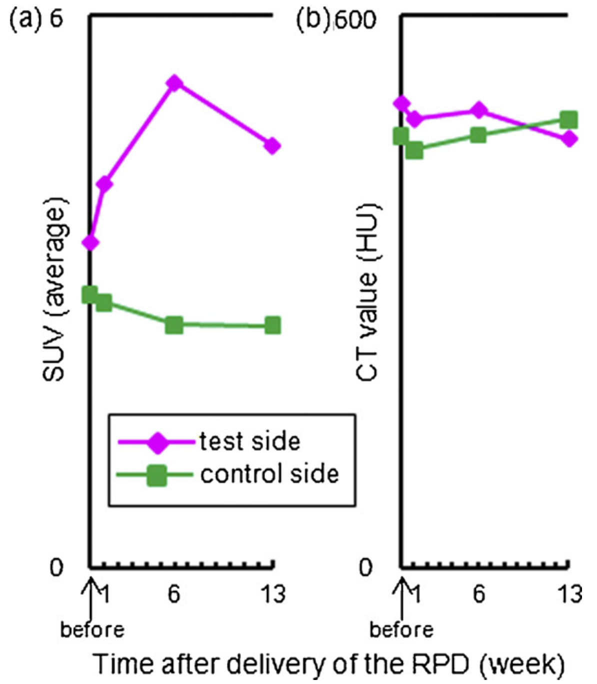

Fig. 7. Changes in the SUVs (a) and the CT values (b) before and after delivery of RPD.

X-ray CT images showed no obvious changes in the bone shape and structure beneath the RPD. The CT values both on the control and test sides did not change either. These results indicated no obvious changes in the bone structure or volume, which could be detective by X-ray CT (Fig. 7b).

3. Discussion

Clear PET images were successfully obtained with low-level radiation exposure (1 mSv during one scan; one fifth of a conventional PET scan) by extending the scan time to 20 min. This enabled us to examine the dynamic and longitudinal processes in the biologic responses of the bone.

Radiographic methods have been predominantly used in human studies of the residual ridge resorption not only in clinical practice. However, in these studies, X-ray images were usually taken before the denture use and a few years afterwards (six months at the earliest) [8–16]. This report shows that NaF-PET could detect bone metabolic changes immediately after the RPD use, which cannot be detected by clinical X-rays. Therefore, NaF-PET should be able to detect unusual changes before problems such as residual ridge resorption occur.

In this report, the SUVs only on the test side increased at 1 and 6 weeks after the RPD use. It may be a mechanobiological reaction to the pressure due to the RPD use. It is well established by a number of animal studies that excessive stress gives rise to bone resorption and bone resorption is a pressure-threshold-regulated phenomenon [1]. Meanwhile, our previous animal studies of bone metabolism beneath the denture base and around the loaded implants using bone scintigraphy [17,18] showed that relatively low mechanical stress, which did not cause the visible change of the bone morphology, initially increased bone metabolism to the peak level, which declined to baseline level with time. In this patient, the SUV changes on the test side showed similar trends to our previous reports, and no pain or inflammation was reported in the denture supporting tissue, implying that raised bone metabolic activities might return to baseline levels after 13 weeks. There is a possibility that the temporary change in the bone metabolism might have related with undetectable micro-scaled changes in bone structure or volume by X-ray CT.

4. Conclusion

This report shows that wearing of an RPD increases bone turnover beneath the denture base immediately after the RPD use without clinically detectable changes in bone structure or volume. The changes in the bone turnover may be temporary and might be related to the process of bone adaptation to the RPD.

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